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ON TO CHAPEL HILL.

BY R. L. SACKETT,
President.

The hospitable south is calling to the members of this Society to gather for their annual convention at North Carolina. Be it known that this state has made greater relative advancement in the last few years in education and transportation than any other state of the Union. There is then certain appropriateness in holding our convention in that state as a recognition of its progress.

The fine highways of Kentucky, West Virginia, Virginia and the central and eastern states call us to make our annual trek to Chapel Hill. The good roads, the beauty of the Old Dominion, and the historical interests of the states through which we would pass are all attractions. The railroad facilities are excellent, the arrangements which our hosts have made are superior and the program is up to the standard which the Society has set in the past. Let us, therefore, gather together for a season of work and of play.

The first great experiment in Engineering Education is drawing to a close and the second of application is before us. The reports of the Board of Investigation and Coordination and of the Director will mark an epoch. It remains for the Society to make correspondingly large plans for the future in order that we may capitalize the money and energy expended in the preliminary stage. A greater responsibility rests on the Society than ever before. The way toward the land of Canaan has been pointed out to us by the prophets. Do we have sufficient confidence in our judgment and the rights of our cause to lead us across Kadesh-Barnea into Canaan—the land of promise?

THE DRAWING GROUP.

At the Chapel Hill meeting the Drawing and Machine Design section will have two meetings and a luncheon instead of the usual single session, and the entire time is to be given to the subject of *Descriptive Geometry.* From advance information received by the chairman of committee 19 there will be more teachers of descriptive geometry and more authors of descriptive geometries at the meeting than have ever before been gathered together. Among other topics the program will include the value and place of descriptive geometry; the correlation of descriptive geometry and drawing; the question of the planes of projection—a debate between the "conservatives" and the "radicals"; a symposium on teaching methods and an exhibition of descriptive geometry drawings and courses.

The importance of and interest in the drawing group was manifested last year at Orono where it had the largest of the sectional meetings. This year with the added time for discussion allowed by the program committee it will be one of the features of the convention. All members engaged or interested in teaching graphics are urged to attend and take part in the discussions and question box.

CONFERENCE ON ELECTRICAL ENGINEERING.

The program on electrical engineering for the annual S. P. E. E. convention is:

"Should a Course in Electrical Machinery Design be Included in the Electrical Engineering Curriculum? If So, How Should It Be Taught?" by A. C. Lanier, Professor of Electrical Engineering, University of Missouri.

"Educational Processes as Employed in Electrical Engineering Department at Massachusetts Institute of Technology," by J. W. Barker, Associate Professor of Electrical Engineering, Massachusetts Institute of Technology, and R. H. Frazier, Instructor in Electrical Engineering, Massachusetts Institute of Technology.

"Place and Value of Advanced Engineering Courses in the Curriculum," by A. S. Hill, Professor of Electrical Engineering, University of Maine.

"Some Aspects of the Electrical Engineering Education Problem," by Chester L. Dawes, Assistant Professor of Electrical Engineering, Harvard University.

"Some Important Factors in the Training of Electrical Engineers," by Leonard P. Dickinson, Professor of Electrical Engineering, University of Vermont.

"Reading for Honors in Electrical Engineering," by Lewis Fussell, Professor of Electrical Engineering, Swarthmore College.

"Electrical Engineering Laboratory Instruction," by D. C. Jackson, Jr., Professor of Electrical and Mechanical Engineering, University of Louisville.

ENGINEERING AT DUKE UNIVERSITY.

BY HAROLD C. BIRD,

Professor of Civil Engineering.

The best route to the annual meeting is through Durham, North Carolina, "the friendly city and center of education." This last statement refers to the fact that Durham is centrally located with respect to the University of North Carolina at Chapel Hill, State College at Raleigh and at the same time being the home of Duke University.

The institution that is now Duke University began its career just ninety years ago as a small school in Randolph County of this state, being known successively as Union Institute, Normal College and for the past seventy years as Trinity College. After an honorable history at Trinity, N. C., the college moved to Durham in 1892 continuing as Trinity College up to December, 1924, when it became the nucleus of Duke University through the great foundation set up by Mr. James E. Duke.

The indenture which created Duke University also provides for hospitals, orphans, for rural churches and their support, for worn-out preachers as well as for the higher education of white and colored youth. In addition to Trinity College of Arts and Sciences, of which Civil Engineering and Electrical Engineering are now a department, the University will include a Coordinate College for Women—the buildings of which have just been completed (see illustration) and are now occupied by the entire University during the construction of the new buildings on our new 4,500 acre campus located about a mile west of our present location; a Law School—already in existence; a School of Religion, which was formally opened last year; a School for Training Teachers, a School of Business Administration—both of which are now departments of Trinity College; a Graduate School, which was recently established; a Medical School, now in the process of establishment; and an Engineering School.

Not since the world war when the emergency required mass construction of a great hospital at Oteen near Asheville and Camp Green near Charlotte has North Carolina seen such intensive building activity as the new campus presents to-day. Swarms of workmen, piles of supplies, and warehouses of materials send one's memory back to the scenes of those anxious days of a decade ago. There is one fundamental difference, however, in the construction work at Duke University and the construction of an army cantonment: the government was building but for the duration of the war; Duke University is building for all time. Nevertheless at this stage of the construction program the Duke site is not unlike that of a great war-time project.

Leading to the site is a railroad over which the University is hauling stone from its own quarries 16 miles away. Miles of new roadway have been cut through virgin timber; scores of temporary houses for the office force, superintendent, timekeepers, engineers, architects, and large buildings for the storage of materials, a saw mill, a blacksmith shop, and quarters for plumbers and electricians have been built. The large open space, which eventually is to be the mile-long quadrangle of the main group of buildings, at present has the appearance of a railroad freight yard with locomotives plying back and forth with heavily laden cars of stone, steel, sand, cement, etc.

At the site of the medical school and hospital three stories of steel framework have been erected for what will eventually be a mammoth structure of five stores covering nearly five acres.

Stone walls are reaching high on the southern end of the long quadrangle where one of the dormitories and the Union are being erected. The dormitories will be made up of various connected units with courts and colonnades. Indiana limestone trimmings and window frames have already been set in several structures and reveal how exquisitely the details have been worked out.

The new five-story Union will be a veritable city within itself with barbershop, lounges, stores, soda fountains, cafe-

teria, dining halls, bowling alleys and other convenient departments. It will be near the dormitory group and is expected to be the center of student activity.

The latest building to be started is the library, across the chapel court from the Union. These two buildings will be quite similar in proportions. Owing to the size of these structures, it appears unlikely just now that any department

of the university will be able to occupy its new quarters even as early as 1930.

One of the points stressed in Mr. Duke's indenture was that great care and discrimination must be exercised in the selection of students. Our entrance requirements are and have been those of the Southern Association, which call not only for fifteen units but also require graduation from a standard four-year high school.

While a course in civil engineering was established just forty years ago and maintained at a high standard it was discontinued for quite some time. During the past year we have completely revised our courses in civil and electrical engineering. In this, we were influenced to a great extent by the reports of the Board of Investigation and Coordination. It was also decided to change the degree to Bachelor of Science in Civil or Electrical Engineering.

COMPARISON OF NEW CURRICULA AT DUKE WITH RECOMMENDATIONS OF BOARD OF INVESTIGATION.

C.E.			E.E.	
Board.	Duke.		Board.	Duke.
		Humanistic Group.		
6	12	English	6	12
6	6	Eng. or Lang. or Bible	6	6
6	6	Economics	6	6
6	18	Electives	6	12
		Scientific Group.		
18	18	Mathematics	18	21
8	8	Chemistry	8	8
10	10	Physics	10	13
3	elec.	Others	3	—
		Gen. Technology Group.		
6	6	Drawing	6	6
4.5	3	Survey for E.E. or Elec. Eng. for C.E.	2	3
8.5	elec.	Heat Power, Shop	8.5	6
16.5	13	Mechanics etc.	19	11
		Mechanism	4	2
		Major Eng. Group.		
41.5	38		37.5	32
140	138	Total	140	138

Foreign Language is an elective—but if once elected, must be taken for two years.

As these curricula were adopted prior to the receipt of the December Bulletin, it was very interesting to note how well we checked with the opinions of professional engineers contained therein. The electrical engineering curriculum follows the Board's recommendations very closely. In the case of civil engineering, however, the electives were increased so that the course would be more flexible. It has been the writer's observation that many college graduates do not follow the line of work in which they major in college and also that an engineering course with proper electives makes an admirable training for business because of the rigorous training.

At present, engineering instruction is carried on in one of the buildings formerly occupied by the Trinity Park School. We have an excellent and complete equipment for the testing of bituminous materials (located in another building); large drafting room with sufficient furniture of satisfactory type and an ample supply of good field instruments, which will be greatly augmented before the end of this year. We realize that it would not be wise to install large testing machines and arrange completely equipped laboratories in Hydraulics, Highways, etc. in such temporary quarters. Consequently we expect to purchase only such equipment as seems necessary from time to time. During the coming year, we shall probably install apparatus for making the ordinary tests of cement—with the exception of compression—and a few of the lighter machines for highway testing.

Our Electrical Engineering Laboratories contain machinery and instruments for the carrying out of the usual experiments in Direct Current and Alternating Current Circuits and Machinery and High Frequency Alternating Currents. The laboratory work is used to supplement the classroom work and the same instructor carries his class through both the classroom and laboratory work which is only possible where the classes are limited in size. Another advantage of the small section is that many more facilities are available than is usually the case where large sections have to be accommodated at one time.

Practically all of the modern American civil and electrical engineering books are in our departmental library with new books being added constantly. Due to lack of room the files of the technical magazines and many transactions are in the main library.

In conclusion, we are trying to maintain a most cordial attitude toward all the other universities and colleges; we are trying to improve our courses slowly but deliberately, learning what we can from the best universities in the country; and we are trying to add to our equipment gradually but of the best. We hope that the older universities will help us from time to time in regard to many details, so that we may better carry out our trust to the young men of character and determination who have a wholesome and real ambition in life.

THE SUMMER SCHOOL FOR ENGINEERING TEACHERS, SESSIONS OF 1928.

NOTES CONCERNING THE SESSION ON PHYSICS.

BY H. P. HAMMOND,

Associate Director of Investigation.

This article continues the notes concerning the 1928 sessions of the Summer School and gives the staff and program of the sessions on physics. As previously announced, this session will be held at the Massachusetts Institute of Technology from July 9 to 28 inclusive.

The staff and program are being arranged with the cooperation of a special committee of the American Physical Society consisting of W. L. Severinghaus, Columbia University, *Chairman;* A. W. Duff, Worcester Polytechnic Institute; O. M. Stewart, University of Missouri; P. I. Wold, Union College; John Zeleny, Yale University. The program is nearly complete but not entirely so, since efforts to secure two or three prominent speakers in addition to those already engaged are not finally concluded.

STAFF

Director

S. W. Stratton, President, Massachusetts Institute of Technology.

Secretary of the Conference

Parke B. Fraim, Assistant Professor of Physics, Polytechnic Institute of Brooklyn.

Teachers of Physics

Henry Crew, Professor of Physics, Northwestern University.
W. F. Drisko, Professor of Physics, Massachusetts Institute of Technology.
A. W. Duff, Professor of Physics, Worcester Polytechnic Institute.

W. S. Franklin, Professor of Physics, Massachusetts Institute of Technology.
W. L. Severinghaus, Professor of Physics, Columbia University.
O. M. Stewart, Professor of Physics, University of Missouri.
L. H. Young, Assistant Professor of Physics, Massachusetts Institute of Technology.

Educational Adviser

W. F. Dearborn, Professor of Education, Harvard University.

Lecturers

P. W. Bridgman, Professor of Mathematics and Natural Philosophy, Harvard University.
Vannevar Bush, Professor of Electric Power Transmission, Massachusetts Institute of Technology.
C. H. Chatfield, Associate Professor of Aeronautics, Massachusetts Institute of Technology.
Edward U. Condon, Assistant Professor of Physics, Princeton University.
Harvey Fletcher, Research Department, Bell Telephone Laboratories.
G. A. Goodenough, Professor of Thermodynamics, University of Illinois.
A. W. Hull, Research Laboratory, General Electric Company.
R. W. King, Assistant Director of Publication, Bell Telephone Laboratories.
Alexander Klemin, Professor of Aeronautical Engineering, New York University.
F. A. Saunders, Professor of Physics, Harvard University.
H. M. Trueblood, Development and Research Department, American Telephone and Telegraph Company.
(Others to be announced.)

Program

The program of the session is arranged in three principal parts. The first and most extensive deals with methods of teaching the principal divisions of physics, and with the coordination of physics courses with other related subjects of the engineering curriculum. Considerable emphasis is given to the latter phase of the work which will be discussed by the staff members who are teachers of physics and by teachers and practitioners of engineering. The second division of the

program deals with teaching procedures and with educational principles in the abstract. The educational adviser, Professor W. F. Dearborn of the Graduate School of Education of Harvard University, will have an important share in this portion of the work. The third portion of the program includes a series of discourses and demonstrations on technical physics with emphasis on the recent developments in the field of modern physics. In connection with this part of the program visits will be made to a number of the laboratories of the Massachusetts Institute of Technology and of Harvard University. The program also provides a fairly generous allotment of time for recreation.

Monday, July 9

Morning: Registration.
Afternoon: Address of Welcome. S. W. Stratton.
Purpose of the Summer School and Outline of the Program. H. P. Hammond.
Objectives of Undergraduate courses in Physics for Engineering Students. W. S. Franklin.
Discussion.
Appointment of general committees.
Announcements.
Evening: Smoker.

Tuesday, July 10

Morning: Physics in Engineering Curricula: a Review of Present Conditions. A. W. Duff.
Continuation and discussion of the above. A. W. Duff and Members.
Afternoon: General Laws of Learning. W. F. Dearborn.
Continuation and discussion. W. F. Dearborn and Members.

Wednesday, July 11

Morning: Teaching the Fundamentals of Physics: Mechanics. O. M. Stewart.
Continuation and discussion. O. M. Stewart and Members.
Afternoon: Recreation.

Thursday, July 12

Morning: Teaching the Fundamentals of Physics: Heat. A. W. Duff.
Continuation and discussion. A. W. Duff and Members.
Afternoon: General Principles of Teaching. W. F. Dearborn.
Continuation and discussion. W. F. Dearborn and Members.
Evening: Lecture: Atomic Hydrogen. (Speaker to be announced.)

Friday, July 13

Morning: Teaching the Fundamentals of Physics: Electricity and Magnetism. W. S. Franklin.
Continuation and discussion. W. S. Franklin and Members.
Afternoon: History of Physics. Henry Crew.
The Lecture, Class-Discussion and Laboratory in Physics Courses. A. W. Duff and W. F. Dearborn.

Saturday, July 14

Morning: Systems of Units in Physics: Mechanics, Electricity and Magnetism. W. S. Franklin.
History of Physics. Henry Crew.
Afternoon: Recreation.

Monday, July 16

Morning: Teaching the Fundamentals of Physics: Light and Sound. O. M. Stewart.
Continuation and discussion. O. M. Stewart and Members.
Afternoon: Session on Applications of Physics: Aeronautics. Aerodynamics. C. H. Chatfield.
Inspection of Aeronautical Laboratory.
Evening: Illustrated Lecture: Aerodynamic Experimentation. Alexander Klemin.

Tuesday, July 17

Morning: The Function of Laboratory Work in Physics Courses. A. W. Duff.
Organization and Methods of Laboratory Courses. L. H. Young.

Afternoon: Teaching Precision of Measurements. W. J. Drisko.
Symposium on laboratory methods. Staff and Members.

Wednesday, July 18

Morning: Laboratory Equipment and Technique. L. H. Young.
Inspection of Physics Laboratories and of Laboratory Work.
Afternoon: Recreation.

Thursday, July 19

Morning: Session on Modern Physics.
Vacuum Tube Research. A. W. Hull.
Recent Developments in Quantum Mechanics. Edward U. Condon.
Afternoon: Inspection of Harvard Research Laboratories.
Evening: Lecture: (Subject and Speaker to be announced).

Friday, July 20

Morning: Lecture-Demonstrations in Teaching Physics. A. W. Duff.
Continuation and discussion. A. W. Duff and Members.
Afternoon: The Class-Discussion Method in Physics. O. M. Stewart and W. F. Dearborn.
Continuation and discussion. Staff and Members.

Saturday, July 21

Morning: Fundamental Concepts in Physics. P. W. Bridgman.
Problem Work in Physics. O. M. Stewart.
Afternoon: Recreation.

Monday, July 23

Morning: Session on Applications of Physics: Mechanics and Heat.
Coordination of Physics with Mechanics and with Thermodynamics. A. W. Duff.
Thermodynamics. G. A. Goodenough.
Afternoon: Coordination of Physics with Mathematics. O. M. Stewart.
Examination Methods. W. F. Dearborn.

Evening: Lecture: Applications of Modern Physics. (Speaker to be announced.)

Tuesday, July 24

Morning: Session on Applications of Physics: Electricity and Magnetism.
Courses in Principles of Electrical Engineering and the Relations of Physics thereto. V. Bush.
Electric Circuits in Communications. H. M. Trueblood.
Afternoon: Coordination of Physics with Electrical Engineering. W. S. Franklin.
Continuation and discussion. Staff and Members.

Wednesday, July 25

Morning: Session on Applications of Physics: Light and Sound.
Spectroscopy. F. A. Saunders.
Audition. Harvey Fletcher.
Afternoon: Recreation.

Thursday, July 26

Morning: Physics as a Career in Modern Industrial Establishments. R. W. King.
Symposium on the self-advancement of the teacher of physics. Staff and Members.
Afternoon: Dealing with the Student: The Gifted Student; Sectioning on the Basis of Ability. W. F. Dearborn and Members.
Presentation of reports of committees in preliminary form.
Evening: Lecture: Resume of Modern Physics. (Lecturer to be announced.)

Friday, July 27

Morning: Discussion: How May Physics Be Made of More Vital Interest? W. L. Severinghaus.
Laboratory Demonstrations. L. H. Young.
Afternoon: Symposium on teaching methods. Staff and Members.
Analysis of Teaching Methods Presented at the Summer School. W. F. Dearborn.
Evening: Dinner.

Saturday, July 28

Morning: Demonstration-Lecture: The Gyroscope. W. S. Franklin.
Great Physicists as Teachers. A. W. Duff.
Adoption of reports of committees.
Adjournment.

At the time of writing there were thirty-seven applications to attend the physics session, the limit of enrollment having been set at forty. Included in this number were one educational director, thirteen professors, two associate professors, ten assistant professors, eight instructors, and two whose rank could not be determined.

STANDARDS FOR GOOD TEACHING.*

BY CURTIS MERRIMAN

Associate Professor of Education, University of Wisconsin.

Teaching procedure is the resultant of at least five prime factors. The learner must be named first. The entire teaching process is organized for his benefit. It is therefore logical to assume that the nature of this learner should occupy first place in any study of the foundations of good teaching. The teacher is named second because he is employed to direct the learner through the various exercises that make up the formal educational experiences. Society is named third because communities, cities and states annually raise enormous sums of money to make it possible for the learner to have educational advantages. The social heritage in the form of lands, buildings, equipment, standards, customs, ideals, and the like, plays a part in determining what the teacher and the learner may undertake to do. The subject-matter of formal education is named fourth. The peculiar nature of the particular subject, together with the amount to be learned in the allotted time must have some influence upon the teacher's procedure and the rate of pupil advancement. The method of presenting the subject matter is named fifth. This will be determined in part by the prevailing fashion of the day, but ultimately it must be determined by the nature and needs of the learner. These five factors are involved in every teaching act in varying degrees. The ever present personal factors that always stand out are the learner and the teacher. Something can always be done about these two factors without encountering problems of taxation, politics, or the time element which may be involved in referring some matters to the administrative heads. It is also true that any administrative plan for im-

* Based on a lecture delivered before the Wisconsin Session of the Summer School for Engineering Teachers, July, 1927.

proving teaching finally comes down to the success or failure of the individual teacher in his classroom with a class before him. It should be obvious that this is true of the engineering class in mechanics or surveying just as it is true of a kindergarten class. The details may differ, but good teaching must obey sound laws of learning. In the following pages are presented (1) some of these general laws of learning and (2) a brief sketch of some teaching procedures that appear to conform to the laws of learning.

Some General Laws of Learning

What is learning? Many technical definitions have been offered. One says learning is bond formation. Another says it is the establishment of synapses. Still another says learning is modification of later behavior by earlier behavior. These statements are undoubtedly sound but how can a busy teacher use them? He can not see a bond or a synapse. He may be confused by trying to measure the modification of behavior. He needs a definition that he can use every day to determine whether his students are learning anything or not. The following statement goes far to meet all these conditions. Learning is the process of becoming able to do something which one could not previously do. This homely statement provides a means for checking progress. It leads to the acid test of a lesson period. Do the learners know something at the end of the period which they did not know at the beginning? Are they able to do something worthwhile at the close which they could not do at the beginning? This is one of our standards of good teaching. *Every lesson period should yield conscious evidence of real advance in ability to do something worthwhile.*

What are the different kinds of learning? The present tendency is to break away from the former elaborate outlines of the many different kinds of learning and to submit a simple functional classification. It is believed that the following three-fold outline suggests the essential features of the kinds of learning:

1. By habits and skills we mean the activities which have for their purpose the fixing of facts, processes, or laws in the learner so that when one element of the fact or process is presented another one comes into action automatically.

2. By knowledge and creative work we mean those activities which have to do with the discovery and understanding of new facts, new processes, and new principles. The emphasis is upon the initial mastery. The items may or may not need to be carried to the habit level.

3. By appreciation and inspiration we mean those activities which have for their purpose the development of interests, tastes, ideals and ambitions.

These three types are certainly involved in the work of colleges of engineering. The various formulas for stresses must be developed. This is knowledge learning. Many of these formulas must be memorized. This is a form of habit. The successful engineer must develop an ideal of making his project conform to the rigid demands of his formula. He must not shirk in labor or material. This is a matter of building ideals. What has just been mentioned with reference to mechanics can be applied as well in any other phase of engineering. Indeed one may go further and urge that any "complete education" whether cultural or professional will incorporate these three aspects. This type of training will produce engineers who (1) will be able to do the habitual thing in a skillful way, (2) will be able to analyze, understand, and do the new and unusual thing, and (3) will be anxious to grow. In this general situation we find another standard of good teaching. *Good teaching involves proper recognition of all three kinds of learning: habits, knowledge, and ideals.*

Are there any factors or conditions that appear to be involved in all learning, regardless of type? If the learner is the center of the teaching process, the answer to this question must be found in the nature of human beings in general. The question may therefore be restated: Are people in general enough alike in certain respects to make it possible for teachers to base type procedures upon these likenesses? Modern

psychology provides secure foundations for the statement of three such general laws of learning.

The *law of effect* states that the individual tends to repeat and learn quickly those reactions which are accompanied or followed by a satisfying state of affairs. He tends not to repeat or learn quickly those reactions that are accompanied by an annoying state of affairs. Engineering classrooms must therefore be places where the students really enjoy doing worthwhile things even though they be difficult.

The *law of readiness* states that activities that come when the nervous system is all set and ready to act are usually accompanied by satisfaction. Conversely, when the activity takes place without the nervous system being ready, the activity leads to annoyance. It is clear that readiness helps to account for effect. If the learner is asked to do something before he is prepared by maturity or mastery of prerequisites, the result is quite likely to be slow, inefficient learning. It is clear also that these two laws lie at the foundation of good assignments and adequate motivation of all grades of school work. Clear recognition of the importance of these laws will stimulate the teacher to make an intensive study of the order of presenting his subject matter and the details of his assignments. In other words, it does make a difference whether an assignment is made per method *A* or per method *B*.

The *law of exercise* states that when a bond between a situation and a response is used, other things being equal, the force of that connection is strengthened. And conversely, when a bond between a situation and response is not used during a period, the strength of the connection is decreased. This law seems so obvious that it is almost childish to state it, and yet it is not at all unusual for teachers to ignore it. The teacher presents a law or principle today and does it very well. And then some weeks later, he expects the learner to have this material still well in hand without having provided any use of the material during the interval. Good teachers meet this law by devising plans for review, drill, and use of knowledge immediately following initial presentation. This use and ap-

plication of material is just as necessary for university students as for primary children. Of course, the drill and practice devices must differ both in quantity and quality. A corollary of the law of exercise seems to be well established. The learner forgets much more during the short period immediately following learning than he will during a much longer period several days later. Hence it appears to be sound psychology to start each recitation with a snappy review or drill of some important aspect of the preceding day's work. This should be kept up for several days until the matter is firmly established. After that, the review references may become less and less frequent for the given point. If the instructor can afford thirty minutes of total drill for a given point, it is better to distribute this time into three or four short drill periods than to give it in one thirty-minute period.

These three laws underlie the quickness and permanency of all learning. It is difficult to assemble all three into one standard of good teaching. Perhaps the essence of all of them is suggested in the next sentence. *Good teaching builds upon the foundation provided by previous work and does it in such a manner that the learner continually feels that each new fact or achievement marks the completion of some plan or supplies the answer to some long-felt question.*

Some Teaching Procedures

What is the teacher's function in this learning process? The preceding statements of the general conditions for all efficient learning imply that the learning is the result of activity on the part of the pupil. He does not passively absorb learning. It is only self-activity that counts in the end. The essential function of the teacher is therefore one of guidance, of stimulation of interesting effort, and of careful setting of the stage for learning. This process is a long one, but it proceeds by one day or lesson at a time. We shall therefore come closer to the real work of the teacher if we offer a suggested sequence of the steps that the good teacher takes in every lesson or series of lessons. He may not do them in the exact order suggested.

He may not give equal time to the steps. In the end, however, he will have touched each of the items.

1. He will discover what students want to do and on the basis of present status of wants will guide their activities so that they will want to do those things which are most educative. The skillful teacher starts with the present interests and desires of the student, but he does not stay there. He can and does determine what these future interests are to be.

2. He desires and selects appropriate learning exercises. By so doing, he saves the learner from becoming lost in the maze of costly trial and error. It is one of the functions of formal education to pass on to this generation the benefits of centuries of racial experience. The teacher must know the most representative incidents for presentation to the youth. Selection of typical instances from racial experience is really a difficult task.

3. He assigns these exercises. This assignment should be made in such a manner that the learner senses the value of the item and sees something of its relation to preceding topics.

4. He motivates the doing of the exercise. Sometimes this is done by the threat of failure to receive a "grade." The laws of learning suggest the possibility of a higher quality of motivation by the establishment of an intrinsic value for the accomplishment.

5. He gives advice and suggestions in regard to the best ways of doing the exercises. This does not mean that he does the work for them. It does mean supervised study. It means cautioning them about certain costly errors. It means teaching the use of manuals and helps of various sorts. It means a word of direction as to where to look for concrete illustrative material.

6. He tests and evaluates the learner's achievement. Teachers often act as if the giving of tests and the assignment of marks were the greatest part of the work. The real purpose of examinations is to reveal to the student whether he has sufficient mastery to be certified as being ready to undertake a real task in the real work of the world.

7. He must devise and assign supplementary exercises, when the tests show incomplete mastery. This involves recognition of individual differences and definite techniques for taking care of them.

8. He must give direct assistance when it is really needed. This may sometimes mean added information. It may mean a guide question. It may sometimes mean actually doing the entire exercise. In this case there should be some follow-up with another exercise to make sure the learner has mastered the point under consideration.

The function of the teacher is sometimes presented in terms of the following "test check" of a teacher's skill which demands that a successful lesson should do the following:

1. Check up on preparation of assigned work.
2. Correct wrong ideas.
3. Add new information.
4. Make adequate assignment of new work.
5. Provide inspiration for attack upon the new problem.

To summarize, just as the engineer goes over all his calculations and plans and carefully checks for errors and omissions, so we may say: *The good teacher frequently appraises the sequence of details in his classroom procedure. He does not trust to general impression. He tests every item in the light of the general laws of learning.*

How does the learner secure the information which constitutes such a large part of learning? The largest single item in teaching is the knowledge element. These facts, laws, etc., to be sure, are often carried through to habits and to ideals. But it is hard to think of habits and ideals apart from the fact and knowledge foundation. It is, therefore, pertinent to inquire as to the various ways by which facts may be obtained. If there are various ways, the teacher has more than one way by which to appeal to the student. Moreover it is sound practice to support facts by evidence drawn from as many sources as possible.

1. Through *experience*. The learner observes the actual happening. He tries, at first hand, various explanations. He

succeeds sometimes. Other times he fails. This method is therefore often costly from the standpoint of time and energy, but it does have the advantage of being vivid and personal. There is decided satisfaction or annoyance. The method provides much concrete experience which is used later to enliven theoretical and abstract discussion. Telling this experience to a second party often compels the narrator to study his facts more closely and this careful study materially adds to the fund of information. There is therefore sound psychology to support the various kinds of observation lessons, field trips, laboratory projects, and actual tryout ventures. Lack of this actual experience goes far to explain why so many students of mechanics have trouble with certain problems. They have no basis for visualizing the problem. *Good teaching therefore attempts to make all its work seem real by providing well chosen and carefully directed experience and expression.*

2. Through *telling and reading.* Students can not always go to the actual sources of experience. It is therefore sometimes quite legitimate for the teacher to tell all the facts in a straightforward narrative account. This type of work gives us the lecture form of teaching. Another large part of our information is obtained by reading. Students should be trained to make use of both lecture and reading to accomplish several purposes. The particular purpose for which the reading is done, will help to determine how it should be done. Briefly stated, teachers lecture or students read to understand, to remember, to find information, to criticize the author, to supplement the text, to analyze the text, or sometimes to enjoy. *Good teaching will acquaint the student with the various purposes of reading and will train him in the appropriate techniques for the various purposes.*

3. Through *development of a course of thinking.* Some problems do not lend themselves to either of the preceding methods. The learner must reason his way through the problem. The older psychology stressed two kinds of reasoning, inductive and deductive, and teachers developed elaborate techniques for developmental work along each of these lines.

Present psychology gives less attention to the kinds of reasoning and lessons, but it does insist that the learner be trained to do four things.

(*a*) He must clearly define his problem. He must know exactly what he is trying to find out.

(*b*) He must collect sufficient and appropriate data.

(*c*) He must make careful study of his data before he announces any tentative or preliminary conclusions.

(*d*) He must test his conclusions by sufficient verification and application.

Good teaching undertakes to supply the learner with well chosen problems through which he will gain not only the desired knowledge, but a skill in arranging data so that he can solve new problems.

4. Through *uses.* Information is not truly mastered until it has been used. This sometimes takes the form of drill for the purpose of making some responses automatic. At other times, it takes the form of an assigned problem which will necessitate the use of the facts just learned. Perhaps the ideal should be to get the student to the point where he can see the new problem himself and then proceed to solve it himself. This is genuine creative work. *Good teaching insists upon making early use of the facts just learned, in order that the learner may early develop the ability to do new and creative work.*

What is the relation of the general theory presented in the preceding paragraphs to some of the prevailing practices, devices and problems? The somewhat dogmatic statements that are appended to the points listed below are based upon the conviction that learners will work long and hard upon any problem in which they sense a real value. Students are not fundamentally passive and lazy. It is true that we sometimes find them so, but the challenging query remains: Have they not been made so by some unfavorable condition under which they have been compelled to work? The following points are suggested with no attempt to place them in any logical order. Just as the teacher's problems may appear in miscellaneous order, so these points appear.

1. Lecture *vs.* recitation. No general law can be stated. There are times when the class needs the facts quickly and in condensed form. They are not found in any book. At other times, the learner needs to have practice in expression and hence recitation plans. Relate to ways of securing knowledge.

2. The student who goes to sleep. Assuming there is no physical cause such as illness or loss of sleep, the problem is fundamentally one of interest. If he feels the vitality of the question under consideration, he will be alert. Relate to definition of learning, to law of readiness, to motivation of assignments, and to basing knowledge upon experience. If sleepiness and inattention are prevalent, the teacher is usually at fault.

3. Some students always behind. This is a problem of individual differences. Sometimes the student does not know how to study. Sometimes he is mentally dull. Sometimes it is just plain carelessness. Refer to law of readiness and law of effect.

4. Student dislikes subject. This condition may be due to a poor start. He has not mastered the early points well enough to derive any satisfaction from the doing of the later exercises. Student may have no actual experience with which he is able to associate the new information. Relate to ways of securing information, and to law of readiness.

5. Interest in improvement. The student sees no relation to his life purpose. He needs to have some device for checking himself every few days. This suggests the use of norms and of learning curves. What can other students and other classes do in this subject in the time he has spent on it? Relate to motivation, and to consciousness of daily progress.

6. The project idea. There is nothing mysterious about a project. It is a device for making the learner feel the realness of his problem. It has the added value of taking more time than a single question and therefore it should secure continued motivation. Schools of engineering are rich in the opportunity to use the project idea.

7. The student who forgets. He seems to have the work to-

day, but next week it is all gone. He has probably learned superficially. He has not been motivated for that fact beyond the needs of the one day. Relate to deep motivation and to law of exercise.

8. Questioning. Questions should follow a sequence, each question growing out of the preceding one. Ordinarily questions should involve but one major issue. In general, question should be stated before student is named. Teacher should insist upon right answers, and should not hesitate to condemn an incorrect response. In general, avoid *yes* and *no* questions because they require minimum of thinking. Relate techniques of questioning to law of readiness, to value of expression, to consciousness of problem, etc.

9. Kinds of examinations. Many educators now favor almost exclusive use of true-false, multiple-choice, completion, and other forms of the so-called new-type examinations. All have values and should be used. There is much value in the familiar type of problem and essay form of examination. Relate all this to different ways of securing information. Some of these demand extended series of thinking. Others stress modes of expression. The good teacher uses all forms in order to guarantee all kinds of use of information, and to guarantee wealth of associations.

10. Questions from class. If all members of the class are vitally interested frequent pointed pertinent questions should come from the class. If the student is learning the technique of developing problems, he should discover problems of his own. They may not be original to the teacher, but they do represent real creative thinking for the student. Such questions should be invited and encouraged.

11. Group or individual instruction. Strong argument on both sides. Individual instruction guarantees individual mastery but lacks the values that come from "matching wits" and from hearing questions raised by the group. Wise teachers use both methods.

12. Theory courses and laboratory courses. Psychology of motivation and use suggests that it is good practice to combine

theory course with a practical course carried at the same time.

13. Marking and return of examination papers and notebooks. The laws of satisfaction and annoyance suggest that the test papers should be carefully marked and returned at an early date. The satisfaction that results from a task well done and approved fixes that association in mind. The annoyance that results from a failure should prompt the necessary work to fix the correct idea in mind. Examinations should be used as teaching measures as well as for pure testing purposes.

14. The ideal outcome in an ideal class. Every member of the class is deeply interested. Every member is doing as good work in this subject as he is in any other subject. Every member is working to capacity. (The facts of individual differences indicate that some students will excel others, and hence teachers must not expect the slower students to do as much as the brighter.) Every member of the class is so fundamentally interested in the subject that he genuinely wants to do more in the subject after the close of the course.

15. Points for improvement. A recent survey of the teaching of mechanics secured from students the following observations which are stated here in very brief form:

(*a*) Better expression. Both oral and written.
(*b*) Teacher see pupil's side of question.
(*c*) More discussion and explanation.
(*d*) Less emphasis on exceptions.
(*e*) Teachers expect too much in time allotted.
(*f*) More interest and "pep" from both teachers and students.
(*g*) Shorter lectures with chance for application and assimilation of material.
(*h*) Some teachers spend too much time on obvious or irrelevant material.
(*i*) Teachers waste time getting started, checking roll, distributing materials, etc.
(*j*) Instructor talks too much, or has a monotonous voice.

Bibliography.

The preceding statements have been made somewhat dogmatically. The inquiring teacher will want to know something of the experimental evidence upon which the generalizations are founded. A brief bibliography is therefore suggested.

Pyle, Wm. H. *The Psychology of Learning.* Gives in very readable and condensed form the greater part of the experimental evidence upon which the suggestions about drill, reviews, memory, forgetting, etc. are based.

Kilpatrick, W. H. *The Foundations of Method.* Splendid discussion of use of project method. Especially valuable for one who wants to get into the spirit and use of the laws of readiness and satisfaction.

Symonds, P. M. *Measurement in Secondary Education.* Splendid discussion of such topics as New Examinations, Sectioning Classes on Basis of Ability, Diagnosis of Difficulties, Marks and Marking Systems, Informal Testing Plans, etc.

Book, Wm. F. *Learning How to Study and Work Effectively.* Splendid for discussion of interest, fatigue, supervised study, daily study plans. Based upon experimental study of college students.

Gates, A. I. *Psychology for Students of Education.* Splendid survey of main facts in educational psychology.

REDUCING FRESHMAN ELIMINATIONS.*

A Discussion Based upon Bulletins Nos. 1 and 2 of the Investigation of Engineering Education.

BY MAX B. ROBINSON,

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Of every one hundred students admitted to the representative four-year engineering courses of the United States and Canada, only twenty-eight graduate in the normal period of four years. Less than forty ever graduate. This means that sixty or more of the original one hundred give up or fail to obtain their chosen objectives. Over thirty of these students have been eliminated, voluntarily or otherwise, before the beginning of the sophomore year.

Such are the rather startling figures presented by the investigation of engineering education conducted by this Society. And the word "startling" is used advisedly. We have long been aware of too many failures and withdrawals in our own institutions and have perhaps ascribed them to local conditions. But to realize that similar losses in the freshman year are nation-wide, occurring in our oldest and best institutions, and in parts of the country where secondary education has long maintained leading standards, as well as in regions where education is still pioneering, this is but to recognize that something is wrong—especially so when available statistics are said to place engineering eliminations above those in agriculture and the other professions.

The economic loss is not the important part. Though apparently a year is wasted as well as the money and sacrifices of parents, most of the work so far completed can be applied towards a degree in some other curriculum. No effort is with-

* Presented at the organization meeting of the Kentucky Section of the Society, December 17, 1927.

out its reward, and even the student who fails or who recognizes a mistaken choice of pursuit, must gain in enlarged viewpoint, and in general education.

But the point is that this negative method of occupational orientation—trying to discover through the medium of experience and mistakes for what studies or occupations one is unfitted—is too painful and costly to be tolerated wherever avoidable. It not only tends to shake the self-confidence of the student whose fondest dreams have been dashed to pieces, but causes heartache and worry to the parents, annoyance and extra work to the instructors, an erstwhile lowering of the classroom efficiency, and in the case of tax-supported institutions, definitely places the administrators upon an embarrassing defensive before the parents who are paying the taxes.

Before engaging in this discussion, let us point with pride to the monumental studies of this subject that have been made by the Board of Investigation and Coordination assisted by various faculty committees. Let us mention in particular the work of two Committees, first, the Committee on "Engineering Students and Graduates," Dean R. L. Sackett, Pennsylvania State College, Chairman, whose "Study of Engineering Students at the Time of Entrance to College" constitutes the basis of Bulletin No. 1 of the Investigation, and second, the Committee on Admissions and Eliminations, Assistant Dean H. H. Jordan, University of Illinois, Chairman, whose report is contained in Bulletin No. 2 of the investigation.

These reports present studies of thousands of students in as many as 116 institutions fully representative of all types found in the United States and Canada. While there are bound to be many local exceptions and variations, the deductions summarized in these reports may be safely said to indicate the status and trend of Admissions and Eliminations in our engineering colleges today.

It would be difficult indeed to find many important points that these Committees have not thoroughly studied. But just as repetition is necessary in successful pedagogy, so must repetition and increased emphasis be used in considering the

constructive recommendations of the above reports if we are to spur ourselves on in adapting them to our local needs. The preliminary work has been done for us. The question now remains: will we use it as it deserves, or let it sink into the verbal abyss of the countless other reports and investigations that have gone before.

In attempting to reduce the eliminations of the freshman year—thirty out of each hundred admitted—let it not be imagined that anyone advocates any lowering of present standards or necessarily feels that most of those now eliminated should be retained. Many of them are wasting their time in an engineering course, and the college work is undoubtedly better off without them. The point is, some of them should never have chosen engineering, and others should have been held out pending more thorough preparation. Perhaps a minority could have well been retained had the proper personal relations between faculty and students been functioning. Something is lacking in either case.

As condensed from Bulletin No. 2,* the causes of high eliminations include:

(*a*) "The failure of parents to inculcate proper study habits in the home, . . . "

(*b*) "The over diversification of the high school curriculums, with consequent lack in the thoroughness of preparation for college."

(*c*) "The failure of students to adjust themselves promptly to college study requirements."

(*d*) "The failure of the colleges to introduce enough flexibility and stimulus into the methods of the first few weeks to encourage a freshman student to rectify an initial failure." "Initial scholastic delinquency leads quickly to discouragement and dismay at the thought of attaining a goal four years away."

(*e*) "The attempt of students to earn a portion of their way and still carry a full schedule of studies."

* Bulletin No. 2, page 17, "Conclusions From Facts and Promises."

(*f*) "Inadequate information regarding the nature of the engineering profession and the consequent lack of vocational stimulus."

Numerically, the causes of all eliminations are listed as follows for the classes of 1923 and 1924 in twenty-three institutions (Bulletin No. 2, pages 9–10):

Scholastic Failure	53.8%	total 68.9%
Voluntary Change of Course	15.1%	
Financial Reasons	9.1%	
Health, Dismissal for Conduct Unknown, and Other Reasons	22. %	

Several of these reasons, such as financial, health, conduct or family affairs seem as likely to operate at one time of the course as another. But the two reasons above which predominate, namely, scholastic failure and voluntary change of course undoubtedly are most poignant in the freshman year, and if freshman eliminations alone were tabulated, the percentage of losses from these two reasons would probably be higher than just stated. It is the freshman year, therefore, which offers the greatest opportunity for constructive work by the various institutions in accordance with the recommendations of the Bulletins.

That scholastic failure and voluntary change of course are interdependent and almost inseparable is shown by the figures given for the various causes of scholastic failure (Bulletin No. 2, page 11). Here we see that Lack of Ability and Lack of Interest together make up 51.2 per cent of all failures. The disinterested student is a poor student. When a student begins to think seriously about changing his course, he usually ceases to put forth his best effort, and he is listed as an academic failure when the real trouble was a lack of vocational stimulus that would have come with an adequate conception of engineering practice.

As is shown by the report, scholastic failures in the freshman year usually occur in mathematics and may result from preparation insufficient in amount of thoroughness, lack of

ability or lack of application. Preparation insufficient in amount shows up in the students' entrance credits and colleges may use their own judgment as to whether or not they wish to admit the candidate with an entrance condition in mathematics. But lack of thoroughness in high school mathematics, or lack of ability may or may not show up in the grades received. Many a student who has "hit the high points" or who has learned the knack gets good grades in high school with but little fundamental knowledge. And many a plodder utterly lacking in mathematical ability gets a fair grade because faithful effort has appealed to the sympathies of the teacher.

The mathematics instructor in college generally gets the "low down" on most of his students within the first two or three weeks. An early division of an algebra section, for example, into higher, middle and lower thirds would not materially change during the balance of the course. There would be cases, of course, where realization of weakness would spur the student on to satisfactory accomplishment, as well as other cases where a student of real ability would let down in his effort.

One cause of this trouble in mathematics which to the speaker's knowledge has never received sufficient emphasis is the time interim between the completion of Advanced Algebra in high school and college entrance. For example, in the majority of high schools in Indiana, while the time is not prescribed, beginning algebra is studied in the first year of high school followed by a half year of Advanced Algebra in the first semester of the second year. This means that the student begins College Algebra in our engineering schools just two and one-half years stale. Without entrance examinations, which are out of the question for many institutions in the case of graduates from accredited high schools, it is difficult to persuade the embryo engineer to review any algebra before he encounters it in college. And even though the early part of College Algebra in itself may constitute a review, the pace is likely to be so rapid that the slow or ill-prepared student finds

himself trailing near the foot of the class. From the viewpoint of the Engineering College, it would be far better if both Advanced Algebra and Solid Geometry could be covered in the last half of the senior year. In other words, a time interim between Elementary and Advanced Algebra and between Plane and Solid Geometry would not be as serious as a similar time interim between the latter subjects in high school and those which follow in college. Any necessary reviewing of elementary portions could then be done in the proper way and place. Very possibly candidates for engineering could avoid such a time interim entirely and without serious results, by beginning the study of algebra later in the high school curriculum. All that seems needed to put such changes in operation is the cooperation of the secondary school authorities and the decision for or against an engineering course before the senior year.

The plan of sectioning students on the basis of ability is used in many institutions. This plan must presuppose extra time for the slower students or lower standards of accomplishment, or both. Our instructors tried this plan last year and did not like it because of the unfavorable psychological effect on the slower students who in all other subjects attended the same classes as the fast ones. Probably it does not work this way in the larger schools.

This year, rather than repeat last year's experiment of sectioning, our instructors voted to try closer personal contacts with the slower students, prescribing individual tutors in some cases, giving extra help in others, and arranging a few extra class periods for review purposes for those who most needed it.

Several were sent to the Director's office for a friendly interview as to the cause of their difficulty. It is certain that this close individual supervision resulted in greater effort and saved several who would otherwise have given up.

The percentage of conditions and failures this fall under the new plan was 15% as against 14.3% last year, and 31% the year before, when no sectioning or other plan was in operation.

It has been our experience that the student who is successful

in College Algebra has little trouble with Trigonometry or Analytics. As a result of this our mathematics department has requested more time for the Algebra even at the expense of time now allotted the other branches. This matter is now under consideration for next year, also the possibility of putting some of the Analytics over into the second year. Of course, the ramifications of such a plan are apparent to all.

A second major cause of freshman eliminations has been described as the voluntary changing of course. As a *cause* this might be called a *state* of *mind* of the student. He may decide to give up engineering (1) because he fears scholastic failure and lacks moral courage to proceed, (2) because he comes to doubt his own ability for future engineering work, (3) because he discovers latent ability or interest in other lines, (4) because he lacks the stimulus of any adequate conception of engineering work and finds himself disinterested in what he thinks engineering to be, (5) because while interested in the spectacular phases of engineering work he is uninterested in the studies leading to it.

The first two reasons mentioned, involving lack of self-confidence may result from actual lack of ability, or from poor preparation or a general misconception of college ways and requirements. The shock of transition from high school to college is not to be taken too lightly. The "A" student in high school may be lucky to pull "C" in college and the average grader in high school often finds himself on the ragged edge or below when his first engineering grades go home. The defensive on which he is placed before his parents is embarassing to a sensitive nature and the grades themselves often misrepresent an honest effort of the student. Add to this the frequent absence of personal friendship and sympathy which often exists between high school teacher and pupil, and a dash of homesickness, and it is not hard to forgive an occasional desire for easier courses. It is all right to assume that college men are mature persons and should not be "spoon-fed," that too gentle treatment will never make real men and engineers out of them, but let us not go too fast. The first half of the

freshman year should more widely be considered as a period of transition, with a more gradual change from high school to college methods. And the same might be said of the last half of the senior year in high school.

The third reason (for wanting to change course), namely, the discovery of interests or talents in lines other than engineering is a natural phenomenon and may occur with any student at any time. It is possible that such awakenings *would* come more frequently in high school years if more courses in occupational orientation were offered; on the other hand, they *may* be awaiting maturity or the widened point of view that comes from college work.

But the causes of most switching from engineering to other branches result from the lack of any adequate idea of engineering work in practice and of the students necessary to prepare for such work. Such conceptions should form the basis of every decision for or against engineering and should be formed sufficiently early in the high school course to allow intelligent planning to meet college entrance requirements.

The following questions were asked one section of forty-nine cooperative students including civils, electricals and mechanicals, both freshmen and upperclassmen, the latter having had considerable outside contacts with engineering practice in connection with their required cooperative employment:

Q. When did you first consider becoming an engineer?

A.			
	Before high school	14 or 28.6%	
	During first two years of high school	6 or 12.2%	26.5%
	During third year of high school	7 or 14.3%	
	During senior year of high school	9 or 18.4%	
	After graduation	13 or 26.5%	

Q. When did you finally decide to study engineering?

A.			
	Before high school	3 or 6.1%	
	During first two years of high school	4 or 8.2%	22.4%
	During third year of high school	7 or 14.2%	
	During senior year of high school	12 or 24.5%	
	After graduation	23 or 47.1%	

Q. Did you plan your high school course with engineering training in view?

A. Yes ..... 20 or 41%
No ..... 29 or 59%

Q. Did you receive in high school any instruction as to the nature of various occupations or professions?

A. Yes ..... 21 or 43%
No ..... 28 or 57%

Q. If such instruction was not given do you feel it would have been of value to you?

A. Yes ..... 26 or 93%
No ..... 2 or 7%

Q. Did you enter college with a fairly correct idea as to the nature of the engineering profession as you now see it?

The freshmen twelve weeks in college who had not started their co-operative employment replied

Yes ..... 11 or 65%
No ..... 6 or 35%

The upperclassmen with one to four years of half-time working experience in more or less direct contact with engineering work replied

Yes ..... 15 or 47%
No ..... 17 or 53%

The number of cases in this analysis is insufficient to warrant any positive deductions, yet it shows the trend among our own student constituency. It shows beyond doubt that over half the students had not even considered engineering training up to their third year in high school, and that nearly half did not make final decision before graduation. The majority of high school courses were not planned with engineering in view, nor did the majority receive any orientation instruction. The feeling was almost unanimous that such instruction would have been helpful.

These facts in the light of our elimination problem would imply the need for earlier and more earnest consideration of future occupation by high school boys, not that they should specialize earlier at the expense of general education, but toward better preparation and a more intelligent decision at the right time. This makes desirable more occupational instruction, and if the average parent cannot give this at home, it

should have a respected place in the high school curriculum in spite of the diversification of which we already complain. A well-known head of a city school system recently told the writer that while he strongly favored such instruction, it was difficult to find good teachers, that existing departments neither cared nor were able to assume the responsibility, and being an unwanted orphan this instruction was recently abandoned throughout the city, admittedly a step in the wrong direction.

It is not difficult to understand why so many freshmen entertain false ideas of engineering work. The current use of the word "engineer" in advertisements of all sorts, the portrayal of the spectacular in our popular scientific press and the inadequate information possessed by most parents have stimulated the imagination of the young man without giving him the real background of the picture. He sees every engineer as a consultant with professional status instead of an industrial employee as so many of us are. He forgets that prosaic foundations must underlie everything sensational, and that for every engineer who becomes famous for individual accomplishment, there are hundreds who have labored without glory, and yet without whom no success would be possible. And when he begins to see the truth as regards engineering, he forgets that the same truth is universal and underlies all endeavor.

The average adult probably understands engineering even less than does youth. A splendid woman and mother of highest culture recently told the writer she did not allow her son to take mechanical drawing in high school because she did not wish to make a plumber out of him. A faculty member in our arts college was surprised to hear we had design subjects in our curriculum. He did not know that "art" was any part of engineering. Another asked for what trades our course in "Applied Mechanics" prepared one. If Billy is adapt in fixing the electric bell or building a radio, he must have a great talent for electrical engineering. You know "electricity is the coming thing." And if John is handy with tools and keeps

dad's car in good repair, and dislikes English and French and all that, of course he ought to be a mechanical engineer.

These popular conceptions of engineering requirements are supposed to have contributed to the rapid growth of our technical schools, but if so, they have also been a factor in our eliminations. And by the same token they have *kept away much good material.* Many a young man who would have benefited greatly from a technical training has never considered it because the nature of its opportunities has never been visualized. And many another has shied away because of these erroneous popular ideas.

This general situation, in the opinion of the writer, constitutes one of the strongest arguments in favor of the Cooperative System. Through oft repeated and continued contacts with engineering practice on his cooperative employment, aided by the counsel of the coordination teachers who are familiar with the outside environment, the student acquires perspective sufficiently early to make a more intelligent choice of his major interests before the senior year.

Bulletin No. 1, already referred to, has some very pertinent suggestions regarding the guidance of high school students in choosing engineering as a profession. It especially emphasizes joint conferences of high school and engineering teachers, addresses on engineering to high school students and teachers and the distribution of specially prepared literature. Recent notices in the S. P. E. E. JOURNAL indicate that already certain institutions are giving their attention to the preparation of informational literature. It is to be hoped that the Society itself can prepare such a bulletin and supply same in quantities at a reasonable price to our various institutions for such uses as they see fit.

A consistent and concerted effort along the lines already pointed out by the Board should give us within a very few years material better prepared *scholastically* and *psychologically* for the rigorous requirements of engineering training. This would inevitably cut down our present wasteful losses, and should make possible higher standards of accomplishments within the alloted four years.

THE ENGINEER'S ARITHMETIC.

BY EVAN THOMAS,

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I.

Every occupation has its arithmetic. The operations may be so elementary that their arithmetical character may escape attention, but arithmetic of some sort is always present, for the reason that arithmetic has to do with numbers and number is interwoven with man's simplest thoughts and with the commonest experiences of life. We may well believe that a rudimentary idea of number is coeval with rational existence and reflective thought. Doubtless Josephus was correct in his conjecture that Adam was a natural mathematician, a conjecture well in keeping with the proverb that the three oldest interests of mankind are the weather, farming and mathematics.

The contents of the arithmetic will be determined largely by occupational requirements. For the bootblack, the barber and the 5 and 10 cent store clerk the arithmetic of whole numbers answers every purpose. The grocer's, for obvious reasons, must include fractions. The carpenter will need provisions for extracting square root. The surveyor finds it necessary to include in his arithmetic such auxiliary aids as logarithms and the trigonometric functions, while the banker makes free use of a new concept, that of rate per cent.

The engineer, too, whose profession has much to do with measured quantity and numerical calculation, has his arithmetic, with distinctive features definitely related to professional requirements, especially those created by the introduction into his problems of variable quantity. It is not a new branch of mathematics set off from its predecessors by a sharp line of demarcation, but is a natural continuation of what has gone before, and differs from them in about the same way that they differ from each other. Each required a new adjustment

in our way of thinking, the invention of new symbols and the formulation of new rules of operation. The same is true here, and perhaps on a somewhat larger scale than previously. The fundamental idea of this arithmetic, however, is a common possession, which has found its way into colloquial speech, as when we say that a car at a certain moment was going at thirty miles an hour. A careful analysis of this statement will lead to the basal concept of the arithmetic under consideration. The general purpose remains unaltered, to obtain important information by ciphering. The difference in method arises out of the difference in the character of the subject matter and of the information desired. Heretofore we have been dealing with fullgrown magnitudes, but now we are dealing with growing magnitudes and our primary concern is with rate at which the growth proceeds, which presents a somewhat more difficult problem. The central element in the present arithmetic is the differential, and the characteristic operation is what is known as differentiation. A clear and definite idea what is meant by a variable in the sense in which it appears in engineering problems should be firmly established in the mind at the outset.

II.

Variables are things in a state of change and are, therefore, familiar objects in our daily experience. The change may be an increase or a decrease, expansion or contraction. The essential consideration is the fact of change or growth. In order to come within the scope of the characteristic processes of this arithmetic, however, two conditions of growth must be met. First, the growth must be continuous, which means that it is so gradual that the successive steps of the growth can neither be measured nor counted. "You cannot detect any stages in the growth, which flows continuously onward, without pause or hindrance." This rules out a variable sum of money which changes from $5 to $6, a variation which can only take place by measurable and countable increments, which may be one dollar, four quarters or a hundred pennies. In any case the increase takes place by jumps, as it were. The varia-

tions with which this arithmetic deals are not subject to the breaks noticed in changing one sum of money to another, in the fluctuations in the price of wheat, or in the step-by-step movement of a pedestrian. It is more like the variation in the length of a piece of rubber stretched from five to six inches. Here the change is not effected by the additions of measurable lengths but is continuous in the sense that there is no namable length between five and six inches which at some time during the operation the piece does not have. It is also essential to the conception of a variable as used in this connection that the variation shall conform to some definite law, that it shall not proceed in haphazard fashion like the motion of a pencil in dashing off a scribble. Variables are generally represented by the latter letters of the alphabet. Heretofore x has stood for an unknown quantity whose value or values are to be found by the solution of an equation. The number of these is limited at most. Now x stands for a variable whose rate of change is to be investigated. In the former case we were dealing, to use a homely illustration, with a bird perched on the branch of a tree, but in the latter with a bird on the wing.

So far the variable has been referred to as an isolated quantity. But the engineer deals with associated variables, with pairs of quantities so connected that the value of one depends upon the value of the other. The relation between them is expressed by an equation. If any value is assigned to one, the corresponding value of the other can be found by calculation. The variable to which a value or change is assigned at pleasure, the variable under direct control, is called the independent variable. That whose value is computed from the equation is called the dependent variable, or the function. In these paragraphs the dependent variable will generally be called the function, and the other simply the variable. Which shall be regarded as the function and which the variable is a matter of convenience. In practice something in the nature of the problem will suggest a choice.

Variables of this sort abound in the engineer's problems. A case in point is that of a freely falling body. Here $S = 16t^2$,

a formula familiar to every reader of high school physics. Any value can be assigned to t at pleasure, and the corresponding value of s computed. That is, we can find by arithmetic how far the body has fallen during a given time, or its position with reference to the starting point at a given moment. Of course, we could solve for t and find by calculation how long it would take the body to fall a given distance. Other familiar cases of associated variables are the volume and pressure in the cylinder of a steam engine, the electric current and voltage in a circuit, the bending moment and the position of the section in a loaded beam, the volume of a sphere and its radius, the number and its logarithm. Even when a physical change does not take place, it is in our power to think of a magnitude as generated by an orderly movement of one of its elements, and it is often a great advantage to so regard it. A parabolic area, for example, may be thought of as formed by a regulated movement of an ordinate which leads to a very simple method of calculating the area, and again for finding the centre of gravity.

III.

The differential has its natural source in variable quantity and has no significance or utility except in this connection. As the form of the word suggests, a differential is a difference, in this case the difference between two values of a growing quantity and is thus just a portion of the variable. Stated otherwise, it is any addition which a growing magnitude takes on at any stage of the growth. A differential is a definite, measurable and representable quantity measured in the same units as the variable itself. The arithmetical symbol for the differential is formed, according to current practice, by writing the letter d before the variable. If s and t are the variables, connected by the law $S = 16t^2$, the differentials are ds and dt, read "differential s" and "differential t." Care should be taken not to mistake d for a factor and ds for a product. These are single symbols, comparable to $\log x$ or $\sin x$, which enter so largely into the engineer's problems.

The basal problem now is the calculation of the differential

of the function in terms of the assigned differential of the variable; in this case to calculate ds in terms of dt. The process is called differentiation, the characteristic operation of this arithmetic. It is a process by which an equation in variables is transformed into a corresponding equation in the differentials of the variables. Applying the process to $S = 16t^2$ we have $ds = 32t\ dt$. Here dt is any assigned increment to t and is constant, while ds is a computed quantity and in general variable, depending in this case upon t. The factor $32t$, called the differential coefficient, is the value of the ratio of the two differentials. Rules for the calculation of this factor, found in any work on calculus, are few, simple and easily followed.

A comparison of the integral equation with derived differential equation will contribute to a clearer understanding of the central elements of the subject and to some insight into the practical uses of these elements. The integral equation makes it possible to locate the body at a given moment, say at the end of 3 seconds, when it is just 144 feet from the starting point. We know that its velocity is constantly increasing and also that to each position of the body belongs a special velocity, a velocity found at no other point. It is obvious that the velocity at this point or at any other point in the path cannot be found directly by simple division, as would be the case with uniform motion. That is, in $S = 16t^2$ we cannot get the desired information by dividing by t, which would give the average velocity during the whole interval. The desired information is implicit in the original equation, but the differential equation, $ds = 32t\ dt$, provides a means for getting it out directly by division, just as if the motion were uniform, for all we have to do is to divide through by dt, obtaining $ds/dt = 32t$. At the end of 3 seconds and at a distance of 144 feet the velocity is 96 feet per second. Since this velocity belongs to this instant alone it is known as an instantaneous velocity or rate of change. The distinctive feature of ds, or the differential of the function, is now seen to be a number such that divided by the increment of the variable the quotient is the

instantaneous rate of change corresponding to any value of the variable.

It may be advantageous, again, to compare this quotient of differentials ds/dt with a quotient of differences for which the usual symbol is $\Delta s/\Delta t$. The value of the former can be found by differentiation only, while that of the latter can be calculated by familiar arithmetical methods. Let Δt be any addition to t and Δs the corresponding addition to s. Then $S = 16t^2$ becomes $S + \Delta s = 16(t + \Delta t)^2$, and by a little reduction $\Delta S = 32t\ \Delta t + 16\Delta t^2$, $\Delta s/\Delta t = 32t + 16\Delta t$, a quotient of differences which gives the average rate of travel during the interval Δt. On the other hand, ds/dt represents the actual velocity possessed by the body at the beginning of the interval, or the apparent intention of the body at that moment, an intention not carried out because the velocity kept increasing during the interval. Δs is the distance actually passed over in the time Δt, ds is the distance that would have been passed over in the same time had not gravity interfered with the initial intention. This, again, brings out the distinctive feature of the differential of the function, and of the differential coefficient as a rate measurer.

Attention has been concentrated thus far upon the phenomenon of a freely falling body because the phenomenon is a familiar one, because the mathematical statement of it is simple and because it embodies all the essential ideas involved in the differential and the differential coefficient. It is seen now that rates that are variable and do not admit of direct measurement can be expressed in terms of uniform rates which do admit of such measurement. With these additions to our arithmetic we are able to extend our calculations to the determination of the rate of change of any function y with respect to its variable x at any point or corresponding to any value of the variable.

A collapsible framework of deltas (Δ's) similar to that just referred to in connection with quotient of differences is much used by the mathematician in deriving rules for the differentiation of different functions. The engineer, however, is not

so much concerned with the derivation of the rules as he is with their meaning and uses. To trace the steps by which $\Delta s/\Delta t$ slides into ds/dt, and $32t + 16\Delta t$, into $32t$, is a fascinating exercise for the mathematically inclined and the logically fastidious, but what the engineer wants is the perception of the differential and the differential coefficient as living, significant things, and ability to use them with confidence in the solution of problems which would be otherwise difficult or impossible. Happily the validity of the rules is not in question, and a satisfactory understanding of the rules is not bound up with any theory connected with their derivation. In the case under consideration, $\Delta s/\Delta t = 32t + 16\Delta t$, the form which the framework approaches as the collapsing progresses is almost in plain sight, but, in general, to bring into view the final state of things often requires considerable ingenuity and troublesome manipulation. It is in this region that the student encounters concepts and assumptions which seem to conflict with his previous notions of mathematical clarity and exactness. It is a field fertile in mystifications and controversies. This phase of the subject will be examined more in detail in a later issue of the JOURNAL.

IV.

The utility of differential is universally acknowledged by all who are acquainted with it. It is vitally associated with the highest developments in astronomy, physics, engineering and various branches of technology. Differentials are among the most potent agencies by which the science and art of engineering have been advanced. More specifically, among the more immediate practical uses for the engineer is the determination of the maximum and minimum values of various functions, like the bending moment in a loaded girder. The differential provides a simple and systematic method of solving problems of this large and important class, and relieves us from the necessity of resorting to special and usually laborious artifices applicable only to a particular problem. Sometimes it is a convenience to transform a function like $\sin x$ into a series in terms of x itself, when an approximate result suffices or is the

only result possible. Here, again, the differential offers invaluable aid. Problems in curvature, sometimes confronting the engineer in connection with deflections, are properly problems in differential equations. By means of differentiation it is possible to determine the direction of the curve at any point. By far the most important and fruitful use of the differential is in connection with process of integration, the reverse of differentiation. When the rate of growth is given the amount of growth between limits can be found by integration, which means transforming the differential equation into an equation between the variables. The rate of growth may be discovered by experiment, or what is more likely, experiment may suggest an hypothesis. That is, the function is assumed to grow at a certain rate. The relations between the variables is then calculated by the process of integration from this rate of growth, and the result is tested. Using our example again from experiment we may guess that the velocity is in proportion to the time of falling, or $V = gt$. Then $ds/dt = gt$ and $S = \frac{1}{2}gt^2$. The result can now be readily tested. The engineer has to do with a large number of important problems in which the given or known quantity is the rate of growth expressed in terms of differentials, and thus the arithmetic of differentials becomes one of his most useful tools. Scarcely a step can be taken by the engineer who aspires to become a master of the science as well as the art of his profession in which he would not be appreciably aided by familiarity with the meaning and process of integration. Even if one is not engaged in work of a sort which employs or might advantageously employ the differential, an acquaintance with this useful device would still be desirable in that it would give him free access to the best literature of the profession and make him a peer of the best equipped among his fellows.

Its field of possible usefulness is much broader than that of the engineer's. Extensive and successful applications of this arithmetic have been made in life insurance and kindred subjects. Actuarial work abounds in problems involving the use of the differential, problems whose solution would be difficult

or only partially successful without this aid. Many attempts have been made and continue to be made to apply its notation and processes to economics, sociology, biology and even to psychology, the devotees of which are laudably ambitious to catch up with astronomers, physicists and engineers, in whose hands differential equations have yielded such magnificent results. These attempts, however, are premature, to say the least, and are probably doomed to ultimate failure owing to the number and obscurity of the elements entering into the problem and what appears to be the practically unpredictable character of human motives and choices, even on the basis of a mechanistic view of human nature.

V.

Instruction in this branch will keep in view a definite object, to familiarize the student with a kind of ciphering required in engineering practice, in much the same way that the commercial school prepares the scholar to do the ciphering required in the counting room or the bank. The engineer's arithmetic, of course, deals with much more complicated combinations of number than the commercial arithmetic, but the aim of instruction is essentially the same, to put the student in the way of using with confidence and accuracy the ideas and methods of calculation of this arithmetic to the solution of engineering problems. To him the rate expressed by the differential coefficient should be as clear in its meaning as is the rate per cent to the bank clerk. There should be no more haze in the first case about the differential than there is in the second about the increment of time or the amount of the accrued interest.

Attention will naturally be directed to the fact that the differential is essentially an auxiliary quantity, whose function is to aid in the solution of important problems in physical science and engineering. What logarithms are in calculations involving large numbers or what the trigonometric functions are in problems dealing with angular magnitudes, differentials are in problems into which variables enter. Like logarithms

and trigonometric functions, too, differentials are eliminated after they have performed the function for which they were introduced. The differential is not an elusive phantom or a shadowy something far removed from any recognizable practical issue, and the student should be helped to see in it a welcome addition to his professional equipment. To him dx, dy, and similar symbols should have all the quantitative attributes of the variables themselves, should be as real as the Arabic numerals, and be seen as natural extensions of arithmetical vocabulary.

In this connection it would doubtless be advantageous to examine rather minutely the peculiar character of the problems which created the necessity for this new auxiliary and which occupied the minds of the great precursors of Newton and Leibnitz. Matters of this sort cannot, of course, be included in a textbook of reasonable size, but the instructor should be so conversant with the antecedents and background of the subject as to be able to set before the student in an illuminating and attractive way the great goal towards which human genius had been striving so long and patiently and finally so successfully. This course is well fitted to remove one of the chief difficulties encountered by the beginner, namely, "to see what it is all about." The mechanical part generally offers but little trouble.

Instruction should be kept in close touch with physical reality. It was intimate association and patient reflection upon the behavior of visible things that gave to Newton the necessary preparation for the final insight. The engineer's interest in the subject is essentially concrete, and the closer his studies are kept to tangible reality the more sustained will be his interest and the more satisfactory his progress. Differentiation is less likely to appear as a hocus-pocus operation on symbols of the meaning of which one has no conception. It is through this close association with what is going on all about us that the symbols become living, significant things.

Instruction should also have a distinct professional bias, should appeal openly to professional interest, and should be

shaped with reference to professional needs. The arithmetic of variables covers a large field, and some division of labor within this field is essential if the best results are to be obtained. There are whole chapters, interesting in themselves and important in other connections, which should be passed over lightly or omitted altogether by the student of engineering to allow greater concentration upon topics of more immediate professional value. The possible desirability of some such division was probably present in the mind of Sir William Rowan Hamilton when he wrote: "The study of algebra (of which the present subject is a branch) may be prosecuted in these different schools, the practical, the philosophical and the theoretical, according as algebra itself is accounted an instrument, a language, or a contemplation; according as the ease of operation or symmetry of expression or clearness of expression is prized or sought after. The practical man may seek a rule which he may apply. The philosophical person seeks a formula which he may write. The theoretical person seeks a theorem on which he may meditate."

The instruction should, again, be cooperative, in that every department to whose problems differentials are applicable should encourage their use and assist in further elucidation, and should check any tendency to substitute for them any more elementary and cumbersome methods with which the student may at the time feel more at home. No subject liveth unto itself nor can be thoroughly understood except in connection with what has gone before and what comes after. It is only by extended practice that the student can hope to acquire facility in the use of mathematical methods and this practice can come most advantageously from constant use in the various subjects to which it is applicable. Ideas obscurely perceived when the subject is first gone over, by constant applications become clear and assume definiteness of outline. Problems are more likely to be those arising from the practical needs of the engineer and are therefore vastly superior to those invented by the mathematician, or even to physical problems introduced for merely illustrative purposes. In this way a direct appeal

is made to the student's professional interest and ambition, which is no small gain. By constant use the student becomes increasingly appreciative of the needs of new conceptions and new processes. He gains additional insight into their significance, and gradually requires a mental habit which instinctively and correctly applies differentials to the solution of problems which would be otherwise insoluble or soluble only by special devices possible only to the most resourceful and ingenious. Understanding gains immensely by different interpretations to meet different needs. It is only by sympathetic cooperation that the student can be helped to see the dovetailedness of the different parts of his professional course and to see his whole professional education as one organic whole and not a group of more or less unrelated subjects. It is in this way that the ideas take root in the mind, and become an integral part of one's intellectual equipment.

VI.

The mastery of this very useful branch of engineering mathematics is not attended with any prohibitive difficulties. It is true that no royal road to a competent knowledge of it has been discovered; probably no such road exists. It is not a subject for weaklings nor for the mentally unambitious or irresolute, but neither is the engineering profession itself. The development of the theory of this arithmetic is by no means an easy matter, but an intelligent comprehension of the results and the ability to use them are within easy reach of average capacity and reasonable industry. The conception of the differential offers no more difficulty than that of the logarithm or the tangent. The mechanism is simple, the rules are few and easily applied to all problems likely to be encountered in practice, and the utility of the operations is readily perceived. The validity of the processes is not in question, and hence the demonstrational side need form no part of a practical course. It is true the process of integration is not so definitely a matter of rules and is often troublesome, but the ability to evaluate

$$\int x^n dx \quad \text{and} \quad \int \frac{dx}{x}$$

will meet a very high percentage of the demands made upon the student's ability to integrate, and a fair memory, a little ingenuity in reversing the processes of differentiation, common sense in the use of integral tables, and a moderate capacity for divination will take care of the rest. An adequate preparation consists of a good knowledge of elementary algebra, some practice in the construction and interpretation of graphs, a little plane trigonometry and familiarity with a few chapters in high school physics. A study of simultaneous equations in algebra is a good point at which to become acquainted with the subject-matter, namely, related variables, and also with functional notation or language. The calculation of the differentials of the simpler functions and their application to familiar problems in physics and geometry could advantageously precede the study of higher equations, determinants, and other topics not included in advanced algebra.